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ARMY ENGINEER DISTRICT ST LOUIS MO
NATIONAL DAM SAFETY PROGRAM. BUTTERFLY LAKE DAM (MO 30501) AND --ETC(U)
SEP 78 A L JOHNSON

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.		

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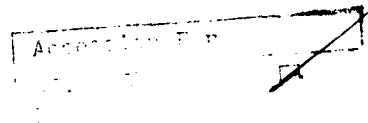
RIVER AUX VASES BASIN
BUTTERFLY AND RAINBOW LAKES
STE. GENEVIEVE COUNTY, MISSOURI

MISSOURI INVENTORY NOS.
BUTTERFLY LAKE MO. 30501
RAINBOW LAKE MO. 30641

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY: ST. LOUIS DISTRICT CORPS OF ENGINEERS
FOR: GOVERNOR OF MISSOURI

SEPTEMBER 1978



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PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Butterfly and Rainbow Lakes
State Located	Missouri
County Located	Ste. Genevieve
Stream	River aux Vases
Date of Inspection	21 August 1978

Butterfly Lake Dam No. Mo. 30501 and Rainbow Lake Dam No. Mo. 30641 were inspected using the "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed by the Chief of Engineers, U. S. Army, Washington, D. C., with the help of Federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines are considered to represent a consensus of the engineering profession.

Based on the criteria in the guidelines, the dams are in the high hazard potential classification, which means that loss of life and appreciable property loss could occur in the event of failure of the dams. Four houses would be subjected to flooding with possible damage and/or destruction and possible loss of life. Butterfly Dam is in the intermediate size classification since it is greater than 40 feet high. Rainbow Dam is in the small size classification because it is greater than 25 feet high.

Inspection and evaluation indicate that the outlet facilities of Butterfly and Rainbow Lakes do not meet the criteria set forth in the guidelines for dams having the above size and hazard potential. Butterfly Dam is an intermediate size dam with a high hazard potential required by the guidelines to pass the PMF. It was determined that the outlet facilities will pass 20 percent of the PMF without overtopping the dam. Rainbow Dam is a small size dam with a high hazard potential required by the guidelines to pass from one-half PMF to the PMF. However, considering the high hazard potential to life (four families) and property downstream of the dam, the outlet facilities should be able to pass the PMF without overtopping the dam. It was determined that the outlet facilities will pass 15 percent of the PMF without overtopping the dam.

The outlet facilities of Butterfly Dam will pass the 100-year flood without overtopping the dam. Rainbow Dam outlet facilities will not pass the 100-year flood. The 100-year flood is defined as a flood that has a 1 percent chance of being equalled or exceeded during any given year.

Since the outlet facilities for the Butterfly Lake and Rainbow Lake Dams are not capable of passing a minimum of one-half (50 percent) of the PMF without overtopping the dam and causing failure, the outlet facilities are considered seriously inadequate and the dams are accordingly classified unsafe, non-emergency structures.

Other deficiencies visually observed by the inspection team were need for removal of brush and small trees on the dam and spillway, and the need for riprap protection at the dam/spillway interface to prevent erosion from high spillway flows. The lack of stability and seepage analyses on record is a deficiency that should be corrected.

It is recommended that the owner take action to correct or control the deficiencies described.

Thomas F. Wolff
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Soils Engineer
St. Louis District
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St. Louis District
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SUBMITTED BY:

Arthur L. Johnson
for Chief, Engineering Division

20 Sep 78
Date

APPROVED BY:

Len E. McK
Colonel, CE, District Engineer

20 Sep 78
Date



Overview of Butterfly Lake, Rainbow
Lake and Kal-Tatri Lake

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BUTTERFLY LAKE DAM - ID NO. 30501
RAINBOW LAKE DAM - ID NO. 30641

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- A. Hydrologic and Hydraulic Analysis Computations
- B. Design Data From 1973 Repairs to Butterfly Lake

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BUTTERFLY LAKE DAM - ID NO. 30501
RAINBOW LAKE DAM - ID NO. 30641

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection of the Butterfly Lake Dam and Rainbow Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. Butterfly and Rainbow Lakes are earth dams which provide recreational lakes for a girl scout camp. Butterfly Lake is the upstream-most of a series of three lakes; Rainbow Lake is in the middle. A third lake, Lake Kal-Tatri, immediately downstream of Rainbow, has a separate owner and was not part of this inspection. Butterfly Lake has a spillway consisting of six 24-inch corrugated metal pipes with concrete headwalls at the left abutment and an auxiliary spillway under construction along a westward extension of the dam axis. Rainbow Lake has a spillway consisting of four 50-inch x 31-inch corrugated metal pipe arches with concrete headwalls at the right abutment.

b. Location. Section 27 and 34, Township 36 North, Range 7 East.

c. Size Classification. Intermediate for Butterfly Lake Dam and small for Rainbow Lake Dam.

d. Hazard Classification. High.

e. Ownership. River Bluffs Girl Scout Council, Glen Carbon, Illinois.

NOTE: The property line reportedly passes through Rainbow Dam, placing the downstream slope on the property of Mr. Kalicak, owner of the other lake downstream.

f. Purpose of Dam. Recreation - Resort Area.

g. Design and Construction History. The dams were built in the mid-1960's (Butterfly, 1962; Rainbow, 1964) by Mr. Kalicak, a contractor and owner of the downstream lake (Kal-Tatri MO. 31039). The dams were acquired by the Girl Scouts in approximately 1967. No preconstruction design information or detailed construction data is known to exist. However, significant remedial work was done to Butterfly Lake in 1973 by Ballman Construction Company. M. B. Corlew & Associates, Edwardsville, Illinois, performed the design and engineering support for the repairs. Repairs included restoration of an eroded area, installation of drains, filling of cracks, spillway repairs, and installation of pore pressure and movement instrumentation. See Appendix B to this report for a drawing of these repairs. Accompanying engineering reports are on record.

h. Normal Operating Procedure. No operating records exist. At both (2) dams, outflow passes through ungated culverts.

1.3 PERTINENT DATA

a. Combined Drainage and Lake Surface Area.

1.83 square miles (Butterfly)
0.89 square miles (between Butterfly and Rainbow)
2.72 square miles (upstream of Rainbow)

b. Discharge at Damsite.

(1) Estimated ungated emergency spillway capacity at maximum pool elevation.

1770 cfs (Butterfly)
1180 cfs (Rainbow)

(2) Estimated culvert spillway capacity at maximum pool elevation.

205 cfs (Butterfly)
405 cfs (Rainbow)

- (3) Estimated experienced maximum flood at damsite - Unknown.

c. Elevation (Feet Above M.S.L.). (Reference to benchmark used by consulting engineer; 802.0 flow line of second culvert at Butterfly Dam.)

- (1) Top of dam (minimum elevation of earth embankment).

808.0 (Butterfly)
771.4 (Rainbow)

- (2) Spillway crest.

803.5 (Butterfly)
767.7 (Rainbow)

- (3) Upstream Outlet Invert.

802.15 (Butterfly)
765.56 (Rainbow)

- (4) Downstream Outlet Invert.

801.71 (Butterfly)
765.26 (Rainbow)

- (5) Maximum tailwater - Unknown.

- (6) Streambed at centerline of dam - estimated.

740 (Butterfly)
735 (Rainbow)

- d. Reservoir. Length of maximum pool.

5200 feet (Butterfly)
1200 feet (Rainbow)

- e. Storage (Acre-feet). Top of Dam Estimated.

1030 (Butterfly)
460 (Rainbow)

- f. Reservoir Surface (Acres).

- (1) Top of dam.

75 acres (Butterfly)
45 acres (Rainbow)

(2) Spillway crest.

65 acres (Butterfly)

35 acres (Rainbow)

g. Dam.

(1) Butterfly Dam.

Type - Earthfill.

Length - 1100 feet.

Height - 41 \pm feet above Rainbow Lake water surface.

Top width - 22 feet.

Side Slopes - 1 V on 3 H.

Zoning - Unknown.

Impervious Core - Unknown.

Cutoff - Unknown; concrete wall 5 feet high by 8 inches wide for entire length of dam, per Mr. Kalicak, original owner and builder.

Grout curtain - Unknown.

(2) Rainbow Dam.

Type - Earthfill

Length - 900 feet

Height - 30.5 \pm feet

Top width - 16 feet.

Side Slopes - 1 V on 2.5 H.

Zoning - Unknown.

Impervious Core - Unknown.

Cutoff - Unknown; none according to Mr. Kalicak, original owner and builder.

Grout curtain - Unknown.

h. Outlet Works.

Types.

6-24-inch cmp (Butterfly)

4-50- x 31-inch cmp (Rainbow)

i. Emergency Spillway. See Section 5, paragraphs 5.1c(3) and 5.1c(4) for a description of each spillway.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No design drawings or data are known to exist for the original construction of Butterfly Dam or Rainbow Dam. However, major repairs to Butterfly Dam were designed by M. B. Corlew & Associates in 1973 after a stability analysis of the then-existing conditions in a slide area. Pertinent design data are included in Appendix B. No detailed stability analyses or seepage analyses of the existing dam are on record.

2.2 CONSTRUCTION

The two dams were reportedly constructed by the previous owner, Mr. Kalicak, a contractor. No detailed information was found to be available. However, Mr. Kalicak, the original owner and builder, stated that the dams were constructed using borrow material from the lake area, placed in less than 12-inch lifts and compacted with sheepsfoot roller. The dams are founded on rock. Mr. Kalicak stated that Butterfly Lake has a 5-foot high by 8-inch wide concrete cutoff wall the entire length of the dam.

2.3 OPERATION

The Girl Scout Council maintains a file of pertinent information regarding repair, major maintenance, engineer's reports, etc. The owner has periodically engaged the engineer to read piezometers and evaluate the dam.

2.4 EVALUATION

a. Availability. Pertinent information is maintained by the owner and the engineer and was made available to the inspection team.

b. Adequacy. The background data and analyses furnished by the owner and engineer and the field surveys and visual inspections presented herein are considered adequate to support the conclusions of this report. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified.

c. Validity. The design of repairs to the Butterfly Dam is considered to have been performed in accordance with good engineering practice.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. Four representatives of the Girl Scout Council accompanied the inspection team. The downstream slope of Rainbow Lake was reported to be off the Girl Scout property, but was inspected by the team. A third, smaller lake, is located immediately downstream but is owned by Mr. Kalicak, the previous owner of the Girl Scout property, and was inspected at a later date and is discussed in a separate report.

b. Project Geology. Thin residual soils cover bedrock of Cambrian age in the vicinity of the lakes. Spillway outlet channels of both dams are cut in fine to medium-grained brown sandstone. The right downstream abutment of Butterfly Dam is formed against a near-vertical rock bluff.

c. Dams. No detrimental settlement, cracks, active slides or sinkholes were observed in or near the embankment. Embankment cross-sections near the maximum height section for each dam are shown on PLATES 3 and 4. These slopes are typical of the overall embankments. An old, healed slide is present on the downstream face of Butterfly Dam at the location of the surveyed section. The owner's engineer has installed 6 piezometers in this section and a row of horizontally aligned metal posts along the mid-slope to monitor movement.

A small seep with an area of cattails about 5 feet square was noted along the right downstream abutment of Butterfly Dam. This seep may be a natural spring from the adjacent rock bluff which was blocked by the embankment. Embankment seepage at Butterfly Dam was corrected in 1973 by installation of a drainage system on the west side. The drainage system outlet was found to be in good condition and not flowing. A trace of silt was present in the bottom of the pipe. No seepage was observed on Rainbow Dam.

At both Butterfly and Rainbow dams, the next lake downstream is near or at the dam toe; however, the lower pools do not submerge the embankment since bedrock foundation generally outcrops at this same location.

Some minor erosion was noted on both dams. A major erosion problem on the right abutment of Butterfly Dam was corrected in 1973 by adding fill and diverting road drainage to a new storm drain along the embankment face.

Both embankments had scattered light brush on the downstream face in addition to the desired turf. If left uncontrolled, such growth could eventually include trees and be a potential seepage hazard. The upstream faces had generally heavier brush and a few small trees. The crown of Rainbow Dam had tall grass and the slopes evidenced less maintenance than Butterfly Dam. The lack of maintenance may be related to the dual ownership of the dam discussed in Section 1.

Based on surface observation, the dams are composed of brown, sandy clays from residual soils in the immediate vicinity. Small rocks are also present.

Small riprap, less than 12 inches, and generally below 6 inches in diameter, is present over much of the upstream slopes, but does not provide complete, uniform coverage. No significant wave erosion was observed; both lakes are short and protected against winds by surrounding hilly topography.

d. Appurtenant Structures. Butterfly Dam has a spillway in the left abutment consisting of six 24-inch corrugated metal pipes with a concrete headwall at either end. During the 1973 repairs, a void beneath the spillway was filled with concrete and a short downstream apron was added. The outlet channel is cut in brown sandstone. A number of small trees are growing up in the outlet channel. The outlet channel is adjacent to the embankment and large flows could threaten erosion of the embankment materials. A flow less than 1 cubic foot per second was occurring at the time of the inspection.

An emergency spillway is being constructed by cutting through and lowering a road along the western extension of the dam axis.

Rainbow Lake has a spillway in the right abutment consisting of four 50- by 31-inch corrugated-metal pipe arches with concrete headwalls. The outflow passes over a recently-constructed short concrete apron and into an outlet channel of brown sandstone. Similar to Butterfly Dam above, large spillway flows could threaten embankment erosion. Trees and dense brush are present in the spillway approach channel and restrict its usefulness.

e. Reservoir Areas. No pertinent problems were noted.

f. Downstream Channel. Both dams have another lake immediately downstream of the rock cut outlet channels discussed above.

3.2 EVALUATION.

Several items are deficient which should be corrected. Brush and small trees on the downstream slope need to be removed on both dams. Riprap or other erosion protection at spillway/embankment interface is needed. Maintenance on downstream slope of Rainbow Dam needs to be increased.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

Operational procedures are nonexistent since the dams have uncontrolled spillways.

4.2 MAINTENANCE OF DAM

An effort at maintenance is evident by the magnitude of past repairs, absence of large trees or erosion, etc. As previously discussed, maintenance at Rainbow Dam is somewhat poorer than at Butterfly Dam. With mowing and removal of brush on embankments and in spillways, maintenance would be considered good.

4.3 MAINTENANCE OF OPERATING FACILITIES

Not applicable.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

No warning system is known to exist.

4.5 EVALUATION

Additional maintenance in the form of mowing and clearing brush from the embankments and spillways is recommended. However, it was evident that the owners have an obvious interest in maintaining the integrity of the dams, as evidenced by their accomplishing major repairs of Butterfly Lake Dam and monitoring the structure under the direction of an engineer.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. A design drawing prepared for a repair contract on Butterfly Lake Dam was provided by the owner. This sheet was a contour map of Butterfly Dam at a contour interval of 1 foot prepared by M. B. Corlew & Associates, Inc. No original design data are available for Rainbow Lake Dam.

b. Experience Data. The drainage area and lake surface area were developed from USGS Sprott and South West Weingarten, Missouri 7-1/2 Minute Quadrangle Maps. The spillway and outlet data were surveyed during the inspection.

c. Visual Observations.

(1) No drawdown facilities are available to evacuate the pool of either Butterfly or Rainbow Lakes.

(2) Low Level Outlets.

(a) The outlet works for Butterfly Lake consists of six 24-inch corrugated metal pipes located at the left end of the dam embankment. The inlet invert elevation is at 802.15 feet. The outlet invert is at 801.71 feet. The tailwater flows through a steep channel cut through rock in the left abutment of the dam. The inlet and outlet of the culvert spillway are protected by concrete head-and-wing walls. Some erosion was noted at the right hand downstream wing wall. The owner's representative stated an intention to provide future protection. (See photographs 7 and 8.)

b. The outlet works for Rainbow Lake consisted of four corrugated metal arches with a span of 50 inches and a rise of 31 inches, located at the right side of the dam embankment. The inlet invert elevation is 765.56 feet. The outlet invert elevation is 765.26 feet. The tailwater flows through a steep channel cut in the rock of the right abutment of the dam. The entrance and outlet have concrete head-and-wing walls. (See photographs 16 and 17.)

(3) Butterfly Lake's emergency spillway is located on the extreme left abutment. The spillway consists of a low natural saddle. The owner has partially degraded a previously placed road fill in the spillway area. Rock is still visible throughout the spillway area. See the profile of the dam. (See photographs 9 and 18.) Flow over the spillway will exit down a small valley that empties into Rainbow Lake. The spillway is judged to be sufficiently stable to pass overflows below the minimum elevation of the earth embankment.

(4) Rainbow Lake's spillway located in the right abutment, adjoining the low head outlets, had small trees growing along the upstream side of it. Spillway consisted of a low section of the dam with a concrete slab as part of it. The concrete slab is arched on the ends. (See photographs 12 and 18.) See the location of the spillway on PLATE 4. The spillway area that was not covered with concrete was generally rock. As discussed in Section 3, large spillway flows could induce erosion of the adjacent embankment.

d. Overtopping Potential.

(1) Butterfly Lake Dam will be overtopped by any flood greater than 20 percent of the Probable Maximum Flood (PMF). The probable maximum flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The spillway section and culverts will pass the 1 percent frequency flood without overtopping the dam. Routing the PMF through the reservoir reveals that the dam would be overtopped for approximately 5.6 hours; depth of overtopping would be approximately 3.1 feet and the maximum discharge approximately 15,900 cfs. A 1 percent frequency flood is a flood with a 1 percent chance of being exceeded in any given year.

(2) Rainbow Lake Dam will be overtopped by any flood greater than 15 percent of the Probable Maximum Flood. Routing the PMF through the reservoir reveals that the dam would be overtopped for approximately 7.4 hours; depth of overtopping would be approximately 4.1 feet and the maximum discharge approximately 23,300 cfs. Rainbow Lake will not pass the 1 percent frequency flood without overtopping.

(3) Since the outlet facilities for Butterfly Lake and Rainbow Lake Dams will not pass one-half (50 percent) of the PMF without overtopping the dam and causing failure, the outlet facilities are considered seriously inadequate.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of the dams and spillways are discussed and evaluated in Sections 3 and 5.

b. Design and Construction Data. These data are discussed in Section 2. While original data on the two dams are not known to be available, substantial data are available for the remedial work done in 1973 to Butterfly Dam. Pertinent data are included in the appendix. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified.

c. Operating Records. See paragraph 2.3.

d. Post-Construction Changes. Major rehabilitation of Butterfly Dam was accomplished in 1973. The work included restoration of an eroded area, installation of embankment drains to control seepage, filling of cracks, spillway repairs, and installation of pore pressure and movement instrumentation.

e. Seismic Stability. Both dams are located in Seismic Zone 2, to which the recommended guidelines assign a "moderate" damage probability. The relatively low dam heights and clayey embankment materials minimize the likelihood of dam failure due to earthquake.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Based on visual inspection and review of available data, the dams appear to be stable and in generally good condition. Brush on embankments constitutes a potential seepage hazard and provides animal habitat. The spillway on Butterfly Dam is inadequate to pass the Probable Maximum Flood (PMF) without overtopping the dam. The spillway on Rainbow Dam is inadequate to pass the Probable Maximum Flood without overtopping the dam.

b. Adequacy of Information. The statements and records herein are based on visual data and information furnished by the owner and the owner's engineer. Butterfly Dam has been repaired based on recommendations by the engineer and has been provided instrumentation for monitoring.

Stability and seepage analyses comparable to the requirements of the guidelines (except for the previous condition of Butterfly Dam) are not on record. This is a deficiency which should be rectified.

c. Urgency. It is recommended that the remedial measures listed in Section 7.2 be accomplished in the near future. The item recommended in paragraph 7.2c should be pursued on a high-priority basis.

d. Necessity for Phase II. No Phase II inspection is recommended. Action should begin on the remedial actions discussed in this report.

7.2 REMEDIAL MEASURES

The following remedial measures are recommended:

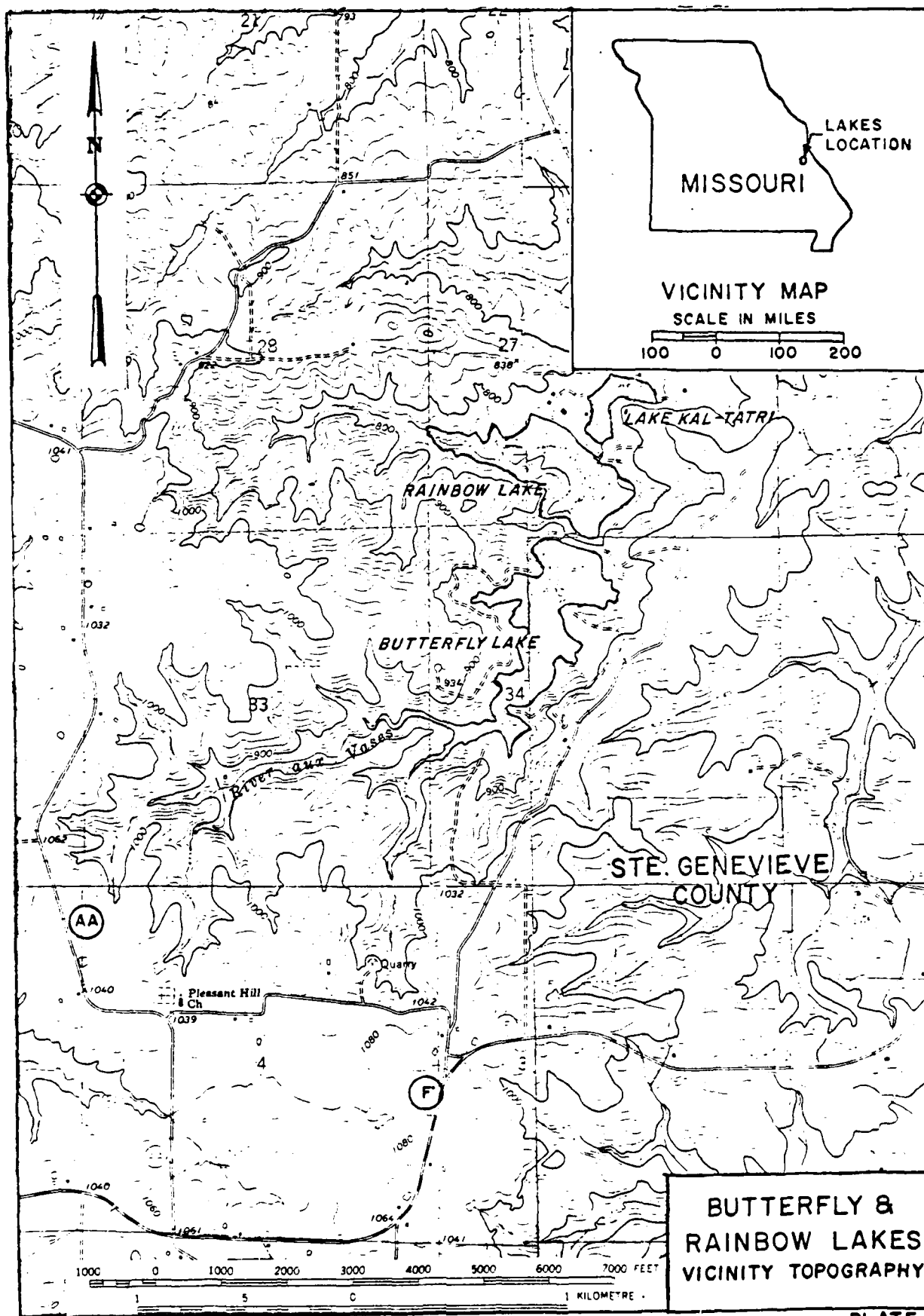
a. Remove brush and mow embankments and the crown of Rainbow Dam. Fill any holes or burrows found.

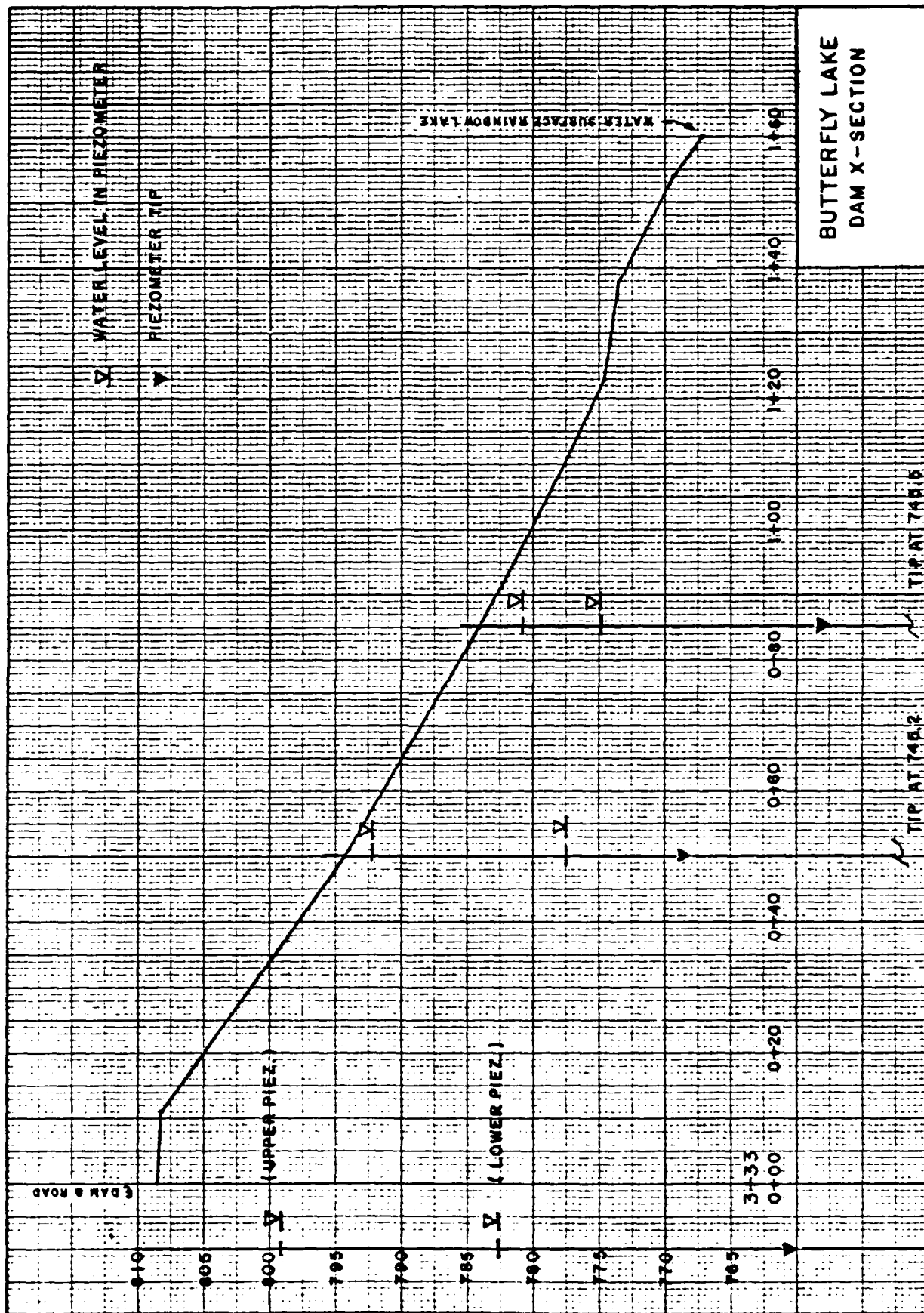
b. Continue the present program of monitoring on Butterfly Dam and periodic evaluation of both dams by an engineer. The owner (River Bluffs Girl Scout Council) is commended for their interest in insuring the safety of their structures by periodic engineering evaluation.

c. Spillway capacity and/or height of each dam should be increased to pass the PMF (Butterfly, 100 percent PMF, Rainbow 100 percent PMF) without overtopping the dam.

d. Operation and Maintenance Procedures.

- (1) Removal of the trees from the entrance of Rainbow Lake spillway would increase the capacity of the spillway as an interim measure.
- (2) Placement of riprap or other protection on the banks at the ends of the wing walls on the tailwater side at both dams. This will minimize the hazard of embankment erosion.
- (3) Complete removal of the earthfill from Butterfly Lake's emergency spillway which will increase its capacity as an interim measure.
- (4) Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of dams.





BUTTERFLY LAKE
DAM X-SECTION

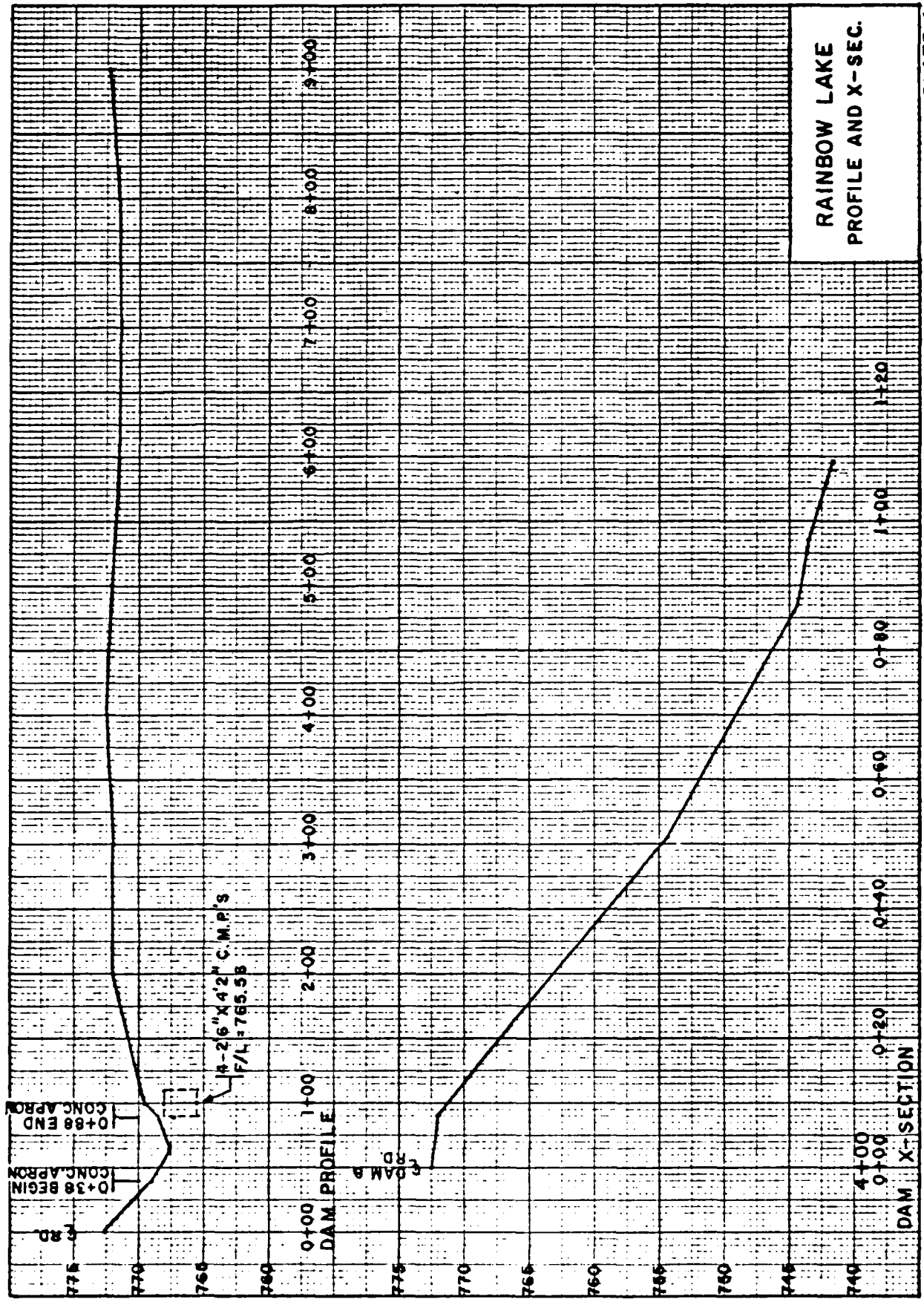




PHOTO 1

Butterfly Dam



PHOTO 2

Butterfly Dam -
Downstream Slope



PHOTO 3 Butterfly Dam - Upstream
Slope



PHOTO 4 Butterfly Dam - Piezometers



PHOTO 5 Butterfly Dam - Seep in
Right Abutment

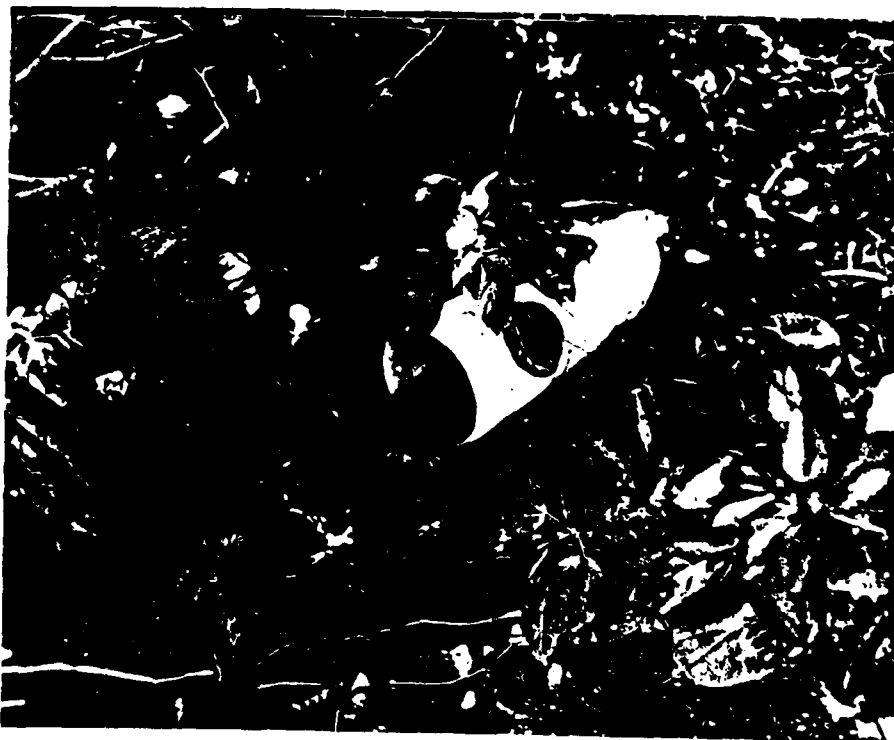


PHOTO 6 Butterfly Dam - Drainage
System Outlet



PHOTO 7 Butterfly Dam - Outlet Channel



PHOTO 8 Butterfly Dam - Outlet



PHOTO 2 Butterfly Dam - Emergency
Spillway



PHOTO 1 Butterfly Dam - d.s. side,
Emergency Spillway



PHOTO 11 Rainbow Lake



PHOTO 12 Rainbow Dam. Emergency
Spillway in Foreground



PHOTO 13 Rainbow Dam - Downstream
Slope



PHOTO 14 Rainbow Dam - Downstream
Slope



PHOTO 15 Rainbow Dam - Upstream Slope



PHOTO 16 Rainbow Dam - Upstream Side
of Outlet



PHOTO 17 Rainbow Dam - Downstream Side
of Outlet



PHOTO 18 Rainbow Dam - Spillway and
Outlet Channel.

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSIS METHODOLOGY

HYDROLOGIC AND HYDRAULIC ANALYSIS METHODOLOGY

1. The hydrologic analysis used in development of the overtopping potential is based on applying a hypothetical storm to a unit hydrograph to obtain the inflow hydrograph for a reservoir routing. The Probable Maximum Precipitation is derived and determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33." Reduction factors have not been applied. A 24-hour storm duration is assumed with the total rainfall depth distributed over 6-hour periods in accordance with procedures outlined in EM 1110-2-1411 (SPF Determination). The maximum 6-hour rainfall period is then distributed to hourly increments by the same criteria. Within-the-hour distribution is based upon NOAA Technical Memorandum NWS HYDRO-35. The non-peak 6-hour rainfall periods are distributed uniformly. All distributed values are arranged in a critical sequence by the SPF criteria. The final inflow hydrograph is produced by deduction of infiltration losses appropriate to the soil, land use, and antecedent moisture conditions.
2. The reservoir routing is accomplished by using Modified Puls routing techniques wherein the flood hydrograph is routed through lake storage. Hydraulic capacities of the outlet works, spillway, and crest of dam are used as outlet controls in the routing. Storage in the pool area is defined by an elevation-storage capacity curve. The hydraulic capacity of the outlet works, spillway, and top of dam are defined by elevation-discharge curves.
3. Dam overtopping analysis has been conducted by hydrologic methods for this dam and lake. This computation determines the percentage of the PMF hydrograph that the reservoir can contain without the dam being overtopped. An output summary in the hydrologic appendix displays this information as well as other characteristics of the simulated dam overtopping.
4. The above methodology has been accomplished for this report using the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California. The numeric parameters estimated for this site are listed in the attached computer printout. Definitions of these variables are contained in the "User's Manual" for the computer program.

[illegible]

DAM		INSPECTION		LAKES					
RAINROW		AND BUTTERFLY		FLOOD					
PROBABLE		MAXIMUM							
JOB SPECIFICATION									
NQ	NUR	NRIN	IDAY	INR	IMIN	NETRC	IPLT	IPRT	NSTAN
248	0	5	0	0	0	0	0	0	0
		JOPER	NUT	LROPT	TRACE				
		5	0	0	0				

MULTI-PLAN ANALYSES TO BE PERFORMED

RTIOS= .10 .15 .20 .25 .30 .40 .45 .50 1.00

SUB-AREA RUNOFF COMPUTATION

SUBAREA= RUNOFF FOR BUTTERFLY LAKE

INVC IUNC TAREA SNAP TRSDA TRSPC RATIO ISHOW ISANE LOCAL

SPPE PMS P6 P12 P24 P48 R72 R96

LROPT STRKR DLTGR RTIOL ERAIN STRKS RTIOX STRTL CNSTL ALSHX RTIMP

CURVE NO = -89.00 WETNESS = -1.00 EFFECT CN = R9.00

UNIT HYDROGRAPH DATA

TC= 0.00 LAG= .25

RECESSION DATA

UNIT HYDROGRAPH 17 END OF PERIOD ORIGINATES, TC= 0.00 HOURS, LAG= .25 VOL= 1.00

537. 1837. 2924. 2278. 1364. 849. 550. 342. 214.

134. 84. 53. 33. 23. 13. 4.

END-OF-PERIOD FLOW

MO-DA	HR-MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO-DA	HR-MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	.00	.01	17.	1.01	12.05	145	.22	.21	.01	1069.
1.01	.10	2	.01	.00	.01	17.	1.01	12.10	146	.22	.21	.01	1328.
1.01	.15	3	.01	.00	.01	18.	1.01	12.15	147	.22	.21	.01	1740.
1.01	.20	4	.01	.00	.01	19.	1.01	12.20	148	.22	.21	.00	2153.
1.01	.25	5	.01	.00	.01	20.	1.01	12.25	149	.22	.21	.00	2476.
1.01	.30	6	.01	.00	.01	20.	1.01	12.30	150	.22	.21	.00	2671.
1.01	.35	7	.01	.00	.01	19.	1.01	12.35	151	.22	.21	.00	2794.
1.01	.40	8	.01	.00	.01	19.	1.01	12.40	152	.22	.21	.00	2875.
1.01	.45	9	.01	.00	.01	19.	1.01	12.45	153	.22	.21	.00	2926.
1.01	.50	10	.01	.00	.01	18.	1.01	12.50	154	.22	.21	.00	2959.
1.01	.55	11	.01	.00	.01	18.	1.01	12.55	155	.22	.21	.00	2981.
1.01	1.00	12	.01	.00	.01	17.	1.01	13.00	156	.22	.21	.00	2996.
1.01	1.05	13	.01	.00	.01	17.	1.01	13.05	157	.26	.26	.00	3029.
1.01	1.10	14	.01	.00	.01	16.	1.01	13.10	158	.26	.26	.00	3114.
1.01	1.15	15	.01	.00	.01	16.	1.01	13.15	159	.26	.26	.00	3245.
1.01	1.20	16	.01	.00	.01	15.	1.01	13.20	160	.26	.26	.00	3374.
1.01	1.25	17	.01	.00	.01	15.	1.01	13.25	161	.26	.26	.00	3474.
1.01	1.30	18	.01	.00	.01	15.	1.01	13.30	162	.26	.26	.00	3535.
1.01	1.35	19	.01	.00	.01	15.	1.01	13.35	163	.26	.26	.00	3573.
1.01	1.40	20	.01	.00	.01	16.	1.01	13.40	164	.26	.26	.00	3599.
1.01	1.45	21	.01	.00	.01	18.	1.01	13.45	165	.26	.26	.00	3616.
1.01	1.50	22	.01	.00	.01	20.	1.01	13.50	166	.26	.26	.00	3627.
1.01	1.55	23	.01	.00	.01	23.	1.01	13.55	167	.26	.26	.00	3634.
1.01	2.00	24	.01	.00	.01	24.	1.01	14.00	168	.26	.26	.00	3640.
1.01	2.05	25	.01	.00	.01	30.	1.01	14.05	169	.33	.32	.00	3678.
1.01	2.10	26	.01	.00	.01	33.	1.01	14.10	170	.33	.32	.00	3799.
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1.01	2.25	29	.01	.00	.01	44.	1.01	14.25	173	.33	.32	.00	4330.
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1.01	3.05	37	.01	.01	.01	68.	1.01	15.05	181	.20	.20	.00	4504.
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1.01	3.30	42	.01	.01	.01	80.	1.01	15.30	186	1.68	1.67	.01	6947.
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1.01	3.45	45	.01	.01	.01	87.	1.01	15.45	189	.69	.69	.00	18492.
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1.01	4.10	50	.01	.01	.01	97.	1.01	16.10	194	.30	.30	.00	8623.
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1.01	4.30	54	.01	.01	.01	104.	1.01	16.30	198	.30	.30	.00	5005.

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1.01	7.40	92	.07	.06	.01	.01	143.	1.01	19.40	236	.02	.00	.00	307.
1.01	7.45	93	.07	.06	.01	.01	144.	1.01	19.45	237	.02	.00	.00	307.
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1.01	8.40	104	.07	.07	.01	.01	155.	1.01	20.40	248	.02	.00	.00	307.
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1.01	8.55	107	.07	.07	.01	.01	158.	1.01	20.55	251	.02	.00	.00	307.
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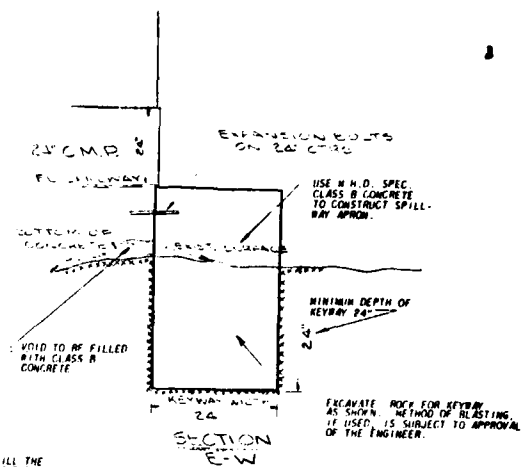
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1.01	9.30	114	.07	.07	.00	.958.	1.01	21.30	258	.02	.02	.00	307.
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1.01	9.45	117	.07	.07	.00	.964.	1.01	21.45	261	.02	.02	.00	307.
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1.01	9.55	119	.07	.07	.00	.967.	1.01	21.55	263	.02	.02	.00	307.
1.01	10.00	120	.07	.07	.00	.969.	1.01	22.00	264	.02	.02	.00	307.
1.01	10.05	121	.07	.07	.00	.970.	1.01	22.05	265	.02	.02	.00	307.
1.01	10.10	122	.07	.07	.00	.971.	1.01	22.10	266	.02	.02	.00	307.
1.01	10.15	123	.07	.07	.00	.973.	1.01	22.15	267	.02	.02	.00	307.
1.01	10.20	124	.07	.07	.00	.974.	1.01	22.20	268	.02	.02	.00	307.
1.01	10.25	125	.07	.07	.00	.975.	1.01	22.25	269	.02	.02	.00	307.
1.01	10.30	126	.07	.07	.00	.977.	1.01	22.30	270	.02	.02	.00	307.
1.01	10.35	127	.07	.07	.00	.978.	1.01	22.35	271	.02	.02	.00	307.
1.01	10.40	128	.07	.07	.00	.979.	1.01	22.40	272	.02	.02	.00	307.
1.01	10.45	129	.07	.07	.00	.980.	1.01	22.45	273	.02	.02	.00	307.
1.01	10.50	130	.07	.07	.00	.981.	1.01	22.50	274	.02	.02	.00	307.
1.01	10.55	131	.07	.07	.00	.982.	1.01	22.55	275	.02	.02	.00	307.
1.01	11.00	132	.07	.07	.00	.983.	1.01	23.00	276	.02	.02	.00	307.
1.01	11.05	133	.07	.07	.00	.984.	1.01	23.05	277	.02	.02	.00	307.
1.01	11.10	134	.07	.07	.00	.985.	1.01	23.10	278	.02	.02	.00	307.
1.01	11.15	135	.07	.07	.00	.986.	1.01	23.15	279	.02	.02	.00	307.
1.01	11.20	136	.07	.07	.00	.987.	1.01	23.20	280	.02	.02	.00	307.
1.01	11.25	137	.07	.07	.00	.987.	1.01	23.25	281	.02	.02	.00	307.
1.01	11.30	138	.07	.07	.00	.988.	1.01	23.30	282	.02	.02	.00	307.
1.01	11.35	139	.07	.07	.00	.989.	1.01	23.35	283	.02	.02	.00	307.
1.01	11.40	140	.07	.07	.00	.990.	1.01	23.40	284	.02	.02	.00	307.
1.01	11.45	141	.07	.07	.00	.990.	1.01	23.45	285	.02	.02	.00	307.
1.01	11.50	142	.07	.07	.00	.991.	1.01	23.50	286	.02	.02	.00	307.
1.01	11.55	143	.07	.07	.00	.992.	1.01	23.55	287	.02	.02	.00	307.
1.01	12.00	144	.07	.07	.00	.992.	1.02	0.00	288	.02	.02	.00	307.
SUM										33.80	32.45	1.35	464534.
										(859.)	(824.)	(34.)	(13154.14)

SUMMARY OF DAM SAFETY ANALYSIS

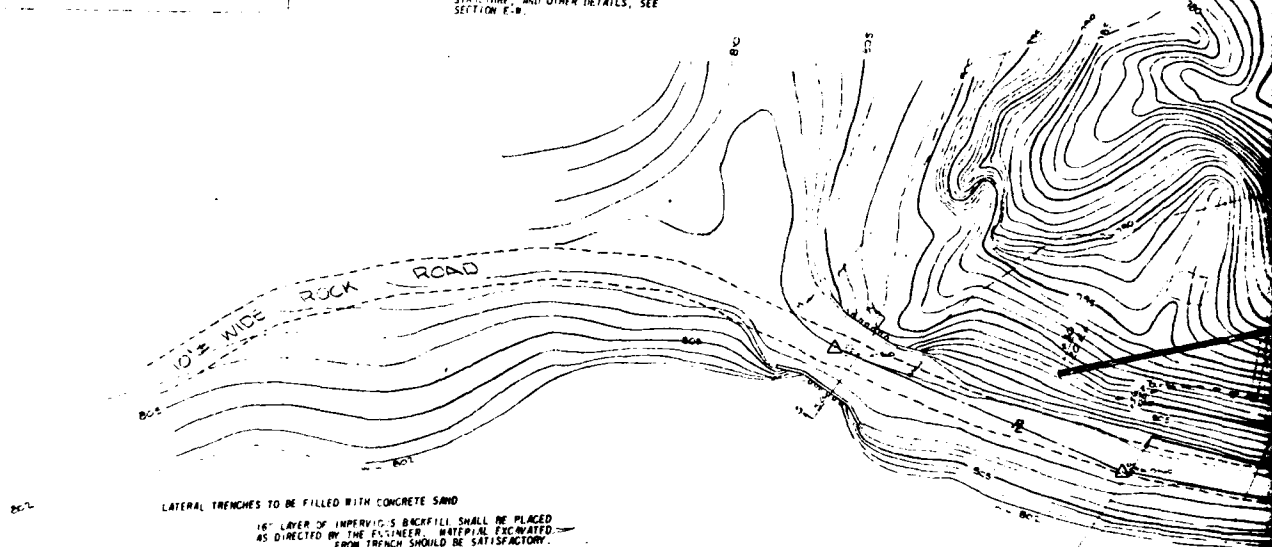
PLAN 1									
ELEVATION		INITIAL VALUE		SPILLWAY CREST		TOP OF DAM			
STORAGE		803.50		803.50		808.00			
OUTFLOW		1442.		1442.		1768.			
		55.		55.		1975.			
SUMMARY OF DAM SAFETY ANALYSIS									
RATIO OF PHF	MAXIMUM RESERVOIR W.S.FLEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS		
.10	805.79	0.00	1604.	371.	0.00	17.33	0.00		
.15	806.65	0.00.	1667.	917.	0.00	16.33	0.00		
.20	807.39	0.00	1722.	1500.	0.00	16.25	0.00		
.25	808.01	.01	1769.	2005.	.17	16.17	0.00		
.30	808.43	.43	1801.	2987.	.83	16.08	0.00		
.40	809.12	1.12	1854.	4841.	1.50	16.00	0.00		
.45	809.38	1.38	1874.	5984.	1.83	16.00	0.00		
.50	809.60	1.60	1891.	6976.	2.25	16.00	0.00		
1.00	811.14	3.14	2014.	15935.	5.58	15.92	0.00		

PLAN 1									
ELEVATION		INITIAL VALUE		SPILLWAY CREST		TOP OF DAM			
STORAGE		767.70		767.70		771.40			
OUTFLOW		343.		343.		471.			
		131.		131.		1644.			
SUMMARY OF DAM SAFETY ANALYSIS									
RATIO OF PHF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS		
.10	769.45	0.00	403.	567.	0.00	17.17	0.00		
.15	770.79	0.00	450.	1146.	0.00	16.92	0.00		
.20	771.74	.34	483.	1979.	1.42	16.42	0.00		
.25	772.32	.92	504.	3056.	2.58	16.17	0.00		
.30	772.82	1.42	522.	4354.	3.08	16.08	0.00		
.40	773.56	2.16	549.	6990.	4.33	16.08	0.00		
.45	773.94	2.54	563.	8483.	4.92	16.00	0.00		
.50	774.07	2.67	568.	12762.	5.33	15.92	0.00		
1.00	775.50	4.10	621.	23284.	7.42	15.92	0.00		

1. FILLING VOID BETWEEN ROCK AND SPILLWAY WITH CONCRETE.
2. EXCAVATING KEYWAY IN ROCK AS DIRECTED BY THE ENGINEER.
3. CONSTRUCTING CONCRETE APRON KEYED INTO REDROCK, WITH ANCHORS TO EXISTING SPILLWAY (EXPANSION BOLTS).



- THE CONTRACTOR SHALL FILL THE VOID BETWEEN THE ROCK AND THE EXISTING CONCRETE WITH CLASS B CONCRETE IN A MANNER SATISFACTORY TO THE ENGINEER. ALL REINFORCED ROCK MATERIAL AND DEBRIS SHALL AS FAR AS POSSIBLE BE REMOVED FROM THE CAVITY FOR ROCK REMOVAL NORTH OF EXISTING STRUCTURE. EXTENSION OF STRUCTURE, AND OTHER DETAILS, SEE SECTION F-9.



16" LAYER OF IMPERVIOUS BACKFILL SHALL BE PLACED AS DIRECTED BY THE ENGINEER. MATERIAL EXCAVATED FROM TRENCH SHOULD BE SATISFACTORY.

THEY'LL WIN.

FINE AGGREGATE (MSD) -
100'S 2 4 1'S SHALL BE
PLAYED IN 2' LAYERS AND
COMPACTED BY VIBRATION

THE NEW YORK PUBLIC LIBRARY
ASTOR LENOX TILDEN FOUNDATION
155 WEST 42ND STREET
NEW YORK 36, N.Y.

REMOVE ALL RIPPABLE
HEAVYWEIGHT ROLL MATERIAL
FROM TRENCH AS DIRECTED
BY THE ENGINEER

DETAIL OF LATERAL VIEW
NOT TO SCALE

LATERAL TRENCH FILLED WITH
CONCRETE SAND (FINE AGGREGATE)

EXISTING GROUND SURFACE

16" IMPERVIOUS M
OVER HEADER & LA
TRENCHES

COARSE AGGREGATE
IN HEADER TRENCH

6- PERFORATED
HEADER TRENCH

TRENCH BOTTOM IS TOP OF
UNWEATHERED BEDROCK WHERE
LESS THAN 10 FEET BELOW
GRAVING SURFACE

TYPICAL SECTION OF LATERAL TRENCH
NOT TO SCALE

5.0' LATERAL TRENCH 30 FEET FROM
BASE LINE UNLESS OTHERWISE
DIRECTED BY THE ENGINEER.

10'-0" FROM GROUND SURFACE
OR
TO UNWEATHERED BEDROCK

DETAIL OF HEADER TRENCH
NOT TO SCALE

COARSE AGGREGATE (MINIMUM
1001.1.5) PLACED AND
COMPACTED AS DIRECTED
BY THE ENGINEER.

TRENC

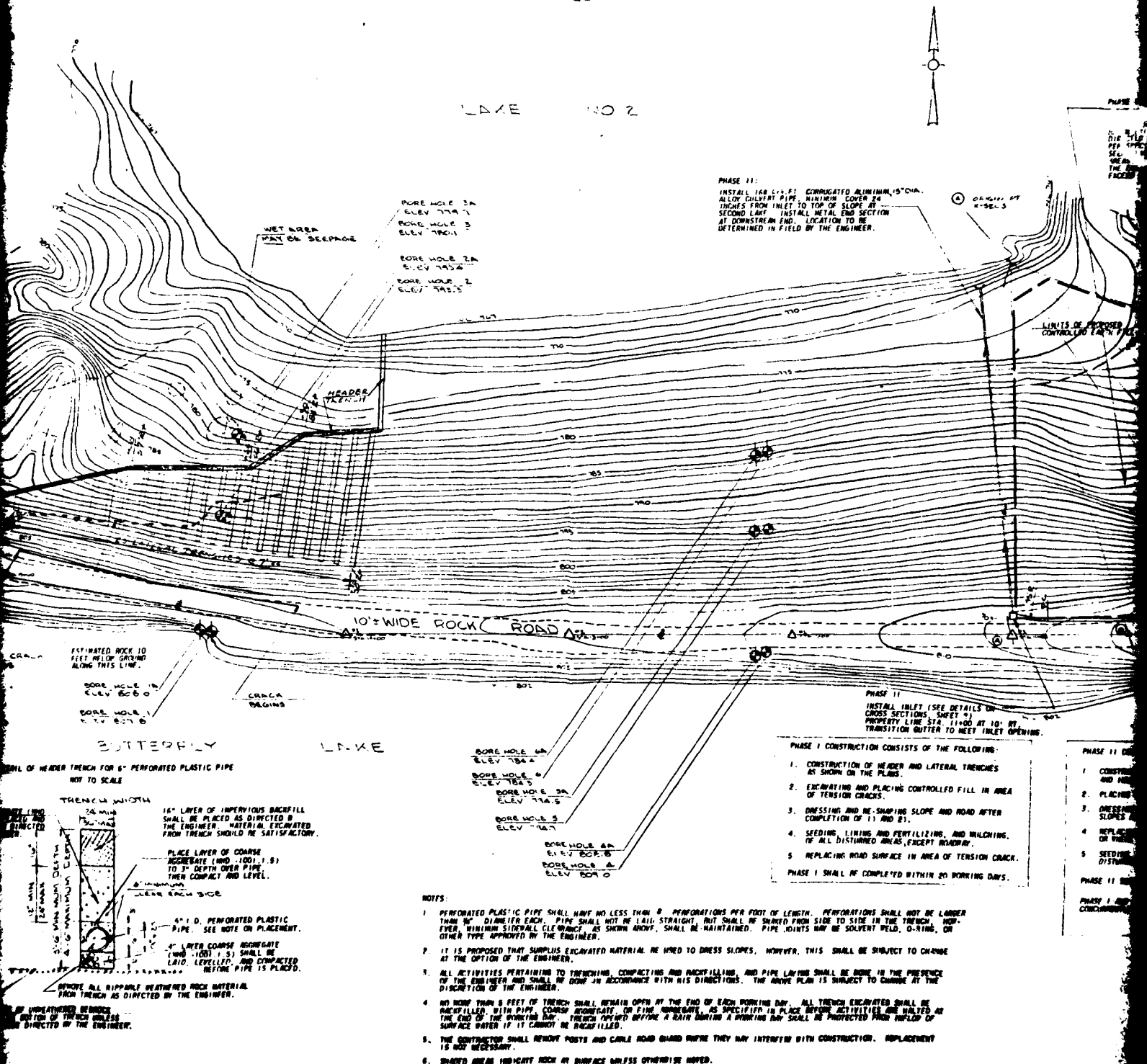
DATE 1/10/10
BY 10/10/10
DIRECTED
BY

SURFACE OF UNWEATHERED OR
SMALL BE BOTTOM OF TRENCH
OTHERWISE DIRECTED BY THE

REMARKS TO BUTTERFLY LAKE DAM SITE FARMINGTON, MISSOURI

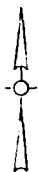
M. B. COHLEW & ASSOCIATES, INC.
ENGINEERS & SURVEYORS
ELWOODSVILLE, ILLINOIS
SEPTEMBER 1973
SCALE 1"=20'

NOTES: CONTOUR
B.M. ELEV.
PIPE FROM
SPILLWAY



TE

NOTES: CONTOUR INTERVAL IS ONE FOOT.
B.M. ELEV. 802.0 IS F.L. OF 2ND
PIPE FROM WEST END OF
SPILLWAY.



PHASE II:
INSTALL 148 L.I.F. CORRUGATED ALUMINUM 15" DIA.
ALLOY CULVERT PIPE, RISING 24
INCHES FROM INLET TO TOP OF SLOPE AT
SECOND LANE. INSTALL METAL END SECTION
AT DOWNSTREAM END. LOCATION TO BE
DETERMINED IN FIELD BY THE ENGINEER.

PHASE II:

PLACE APPROXIMATELY 2500 CUBIC YARDS CONTROLLED EARTH
FILL TO SLOPED SHOWN ON CROSS-SECTIONS (SHEETS 2-4).
REINFORCE EXISTING SLOPES AND STRIP VEGETABLE MATTER AS
DIRECTED BY THE ENGINEER. FILL SHALL BE PLACED AS
PER SPECIFICATIONS (95% COMPACTION). RESHAPE SLOPE,
SEED, LIME, FERTILIZE AND MULCH IN ALL DISTURBED
AREAS. PROPOSED BORROW SOURCE MUST BE APPROVED BY
THE ENGINEER. ESTIMATED HAUL DISTANCE SHOULD NOT
EXCEED 2500 FEET.

PHASE II:

CONSTRUCT 145 L.I.F. CONCRETE CURB
AND GUTTER (SEE DETAIL ON CROSS-
SECTIONS, SHEET 2). GRADE AND EXACT
LOCATION TO BE DETERMINED IN THE
FIELD BY THE ENGINEER. BACKFILLING
AND REPLACING ROAD SURFACE IS
INCLUDED IN PHASE II.

PHASE I CONSTRUCTION CONSISTS OF THE FOLLOWING:

1. CONSTRUCTION OF HEADER AND LATERAL TRENCHES
AS SHOWN ON THE PLANS.
2. EXCAVATING AND PLACING CONTROLLED FILL IN AREA
OF TENSION CRACKS.
3. DRESSING AND RE-SHAPING SLOPE AND ROAD AFTER
COMPLETION OF 1) AND 2).
4. SEEDING, LIME AND FERTILIZING, AND MULCHING,
OF ALL DISTURBED AREAS, EXCEPT ROADWAY.
5. REPLACING ROAD SURFACE IN AREA OF TENSION CRACK.

PHASE I SHALL BE COMPLETED WITHIN 20 WORKING DAYS.

PHASE II CONSTRUCTION CONSISTS OF THE FOLLOWING:

1. CONSTRUCTION OF CULVERT PIPE, CURB AND GUTTER,
AND INLET.
2. PLACING OF CONTROLLED FILL.
3. DRESSING AND RE-SHAPING DISTURBED AREA OF EXISTING
SLOPES AND ROADWAY AND BACKFILLING OF GUTTER.
4. REPLACING ROAD SURFACE WITH GRAVEL WHERE REQUIRED,
OR THERE DIRECTED BY THE ENGINEER.
5. SEEDING, LIME AND FERTILIZING, AND MULCHING OF ALL
DISTURBED AREAS EXCEPT ROADWAY.

PHASE II SHALL BE COMPLETED WITHIN 20 WORKING DAYS.

PHASE I AND PHASE II MAY BE CONSTRUCTED
CONCURRENTLY.

PERFORATIONS PER FOOT OF LENGTH. PERFORATIONS SHALL NOT BE LARGER
STRAIGHT, BUT SHALL BE SLOPED FROM SIDE TO SIDE IN THE TRENCH. HOW-
EVER, SHALL BE MAINTAINED. PIPE JOINTS MAY BE SOLVENT WELD, O-RING, OR

BE USED TO DRESS SLOPES. HOWEVER, THIS SHALL BE SUBJECT TO CHANGE

AND BACKFILLING, AND PIPE LAYING SHALL BE DONE IN THE PRESENCE
OF THE ENGINEER. THE ABOVE PLAN IS SUBJECT TO CHANGE AT THE

END OF EACH WORKING DAY. ALL TRENCHES EXCAVATED SHALL BE
REINFORCED, AS SPECIFIED IN PLANS, BEFORE ACTIVITIES ARE HALTED AT
THE END OF A WORKING DAY. SHALL BE PROTECTED FROM FLOODING OF

ROADWAY WHEN THEY MAY INTERFERE WITH CONSTRUCTION. REPLACEMENT

SHALL BE NOTED.

2

APPENDIX B 3

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